PROJECT TITLE: Circulation in the Vicinity of Descending Overflows

PRINCIPAL INVESTIGATOR: Michael A. Spall

INSTITUTION: Woods Hole Oceanographic Institution

ADDRESS: Michael Spall, MS #21
360 Woods Hole Road
Woods Hole, MA 02543-1541

TELEPHONE: (508) 289-3342

FAX: (508) 457-2181

e-mail: spall@cms.whoi.edu

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LONG TERM GOALS

The long-term goal of this project is to contribute to our understanding of the circulation, exchange, and environment between marginal seas and the open ocean.

OBJECTIVE

To better understand the mean and time-dependent circulations induced in the upper ocean by turbulent entrainment in the vicinity of steep bottom topography.

APPROACH

Idealized numerical modelling studies are used in conjunction with theory to understand the large scale circulations that are forced by entrainment into spatially variable mixing regions. The results are interpreted and understood by making use of potential vorticity budgets, integral constraints, and thermodynamic balances. Geometries under study include: entrainment in the open ocean, entrainment near steep topography, and entrainment near ridges and seamounts.

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WORK COMPLETED

An isopycnal model has been applied to the study of the large scale circulation induced by localized diapycnal mixing in simply and multiply connected domains. Analytic boundary layer solutions have been developed to quantify the dissipation resulting from mixing near boundaries. Fundamental integral constraints have been developed to interpret the resulting circulation patterns and transports as a function of the mixing and topographic parameters.

A nonlinear analytic two-layer model has been developed to study the circulation forced by spatially variable diapycnal mixing over a sloping bottom. Two non-dimensional numbers control the strength of the horizontal circulation and the importance of the nonlinear terms. A series of idealized calculations and an application to the circulation in the deep Brazil Basin have been completed.

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Analytic models of the wind- and buoyancy-forced circulation in

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marginal seas have also been developed and applied to the circulation around Australia and the circulation in the Sea of Japan.

RESULTS

The strong, large-scale horizontal recirculation that is forced by open ocean diapycnal mixing is gradually replaced by a weak, unidirectional flow into or out of the mixing region as the mixing is confined near a horizontal boundary. The viscous potential vorticity flux into the boundary replaces the strong horizontal recirculation gyre in the potential vorticity budget. However, if this mixing is along the western side of an island or mid-ocean ridge, the dissipation within the mixing region requires that a strong, large-scale horizontal circulation flow around the topography, connecting the adjacent basins and sometimes extending far from the region of mixing. Diapycnal mixing in the open ocean to the east of an island or ridge also requires a horizontal circulation around the topography to the west.

A meridional gradient in sea surface temperature forces an eastward geostrophic flow in the upper ocean. A buoyancy-forced boundary current is formed as this flow impinges on an eastern boundary. If the boundary is an island, then constraints imposed by a circulation integral around the island require that a large-scale circulation develop that connects the two basins separated by the island. Application of this model to the circulation around Australia indicates that the transport from the Pacific to Indian Ocean is reduced in the upper 200 m and enhanced at mid-depths compared to that expected from wind-driven theory. The theory compares well with results from an idealized primitive equation numerical model.

Diapycnal mixing over a sloping bottom results in a weak, unidirectional flow into or out of the mixing region in the deep ocean, and a strong horizontal recirculation in the upper ocean. In this inviscid case, the deep recirculation is exactly eliminated by the interaction of the deep flow with the bottom topography, even when the flow is nonlinear. Application of this analytic model to the deep Brazil Basin produces horizontal and vertical circulations that are in good agreement with recent observations.

IMPACTS/APPLICATION

These results indicate that mixing near topography can force strong circulations far from the region of mixing. The exchange between marginal seas and the open ocean will be strongly dependent on whether the marginal sea is connected to the open ocean by one strait (e.g. the Mediterranean Sea) or by two or more straits (e.g. the Sea of Japan). Spatially variable mixing over even a very weakly sloping bottom results in a fundamentally different horizontal circulation than does mixing over a flat bottom.

PUBLICATIONS

Spall, M. A. and R. S. Pickart, 2001. Where does dense water sink? A subpolar gyre example. J. Phys. Oceanogr. {\bf 31,} 810-826.

Spall, M. A., 2000. Buoyancy forced circulation around islands and ridges. in press: J. Marine Res.

Spall, M. A., 2001. Large-scale circulations forced by mixing over a sloping bottom. in press: J. Phys. Oceanogr.

Spall, M. A., 2001. Numerical Modelling: The Forward Problem. Chapter in: Encyclopedia of Ocean Sciences, in press.

Spall, M. A., 2001. Influences of the Leeuwin Current on the baroclinic structure of the Indonesian Throughflow. submitted to: J. Phys. Oceanogr.

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6. AUTHOR(S)
Michael A. Spall

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
800 North Quincy Street
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ATTN: Steve Murray
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14. ABSTRACT
Analytic and numerical models have been used to study the large-scale circulation and exchange between marginal seas and the open ocean resulting from diapycnal mixing near lateral boundaries. The results indicate that mixing near topography can force strong circulations far from the region of mixing, sometimes extending into an adjacent ocean basin. The exchange between marginal seas and the open ocean will be strongly dependent on whether the marginal sea is connected to the open ocean by one strait (e.g., the Mediterranean Sea) or by two or more straits (e.g., the Sea of Japan). Islands and ridges generally provide a very effective means for communication and exchange between adjacent ocean basins. Spatially variable mixing over even a very weakly sloping bottom results in a fundamentally different horizontal circulation than does mixing over a flat bottom.

15. SUBJECT TERMS
Turbulent mixing, marginal seas, bottom topography

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